# Risk Targeted Hazard Spectra for Seismic Design in New Zealand

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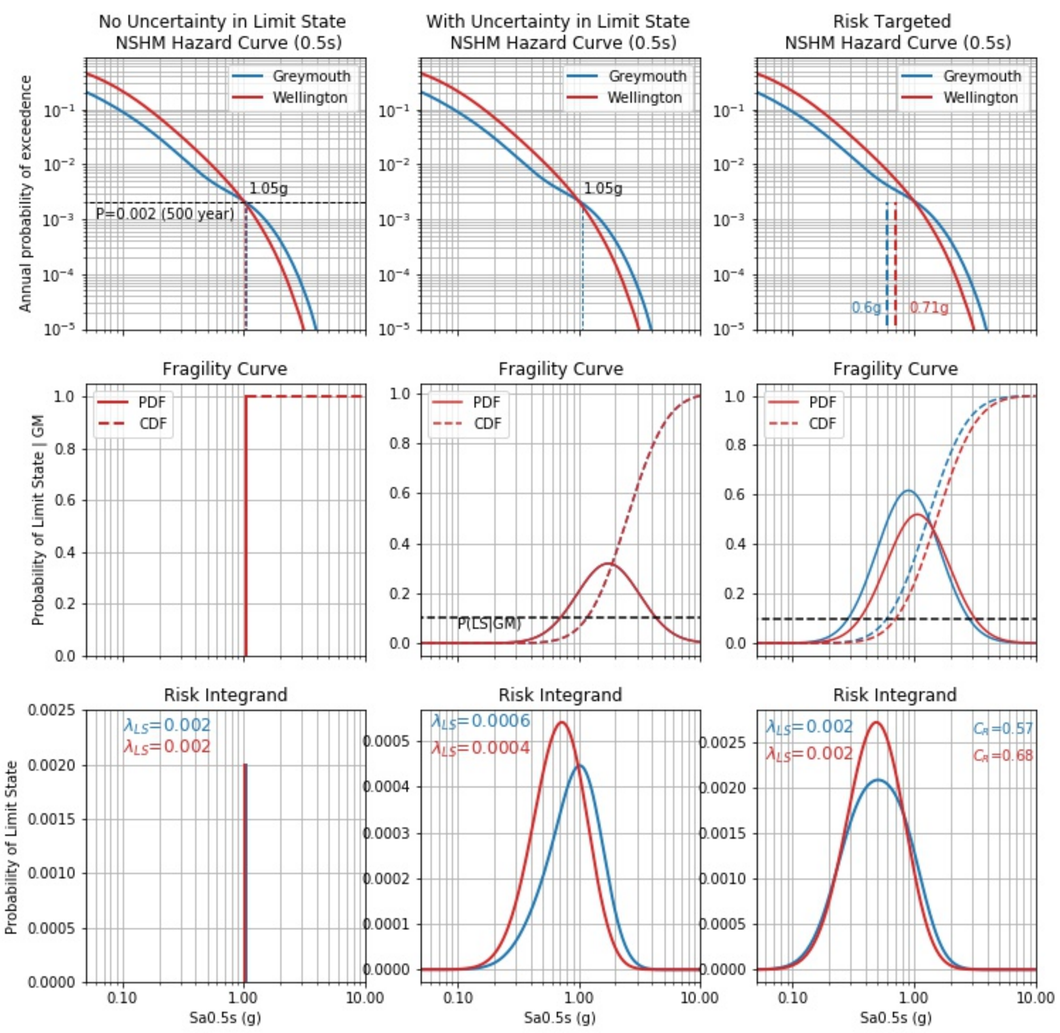
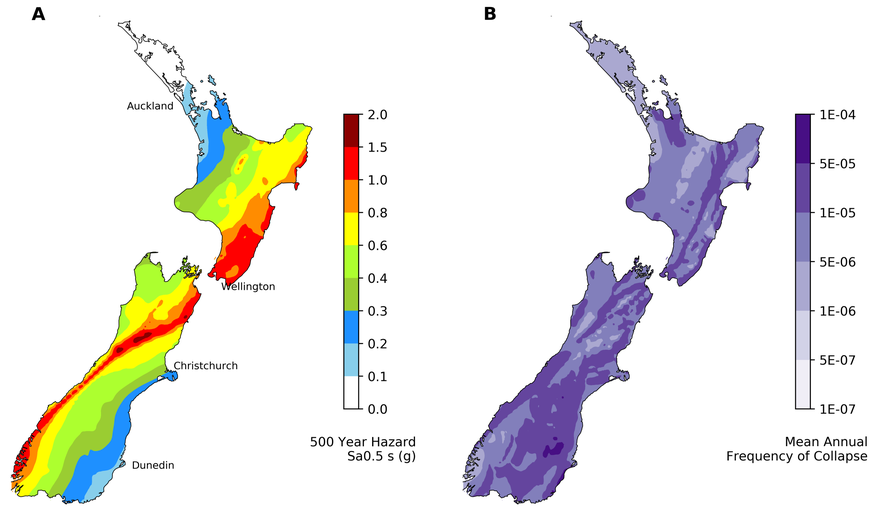
## 1. Introduction

New Zealand, like most countries, has a building code that is based on uniform hazard loading. That is, the design level is fixed to a hazard level with a defined return period (e.g. 1 in 500 year ground motion). Hazard levels above and below the hazard level of interest are ignored.

If we assume there is no variability in building response, then this results in unfirom risk between sites (Left Panels below). However, in reality, as-built buildings have variability in response due to differences in design, construction materials and compliance. This uncertainty in response leads to spatial variability in risk (Middle Panel Below) as now variations in the shape of the hazard curve are important. Risk targeted hazard aims to address this, by designing for a risk target by back-calculating the design level that provides unfirom risk (Right Panel Below) considering all parts of the hazard curve.

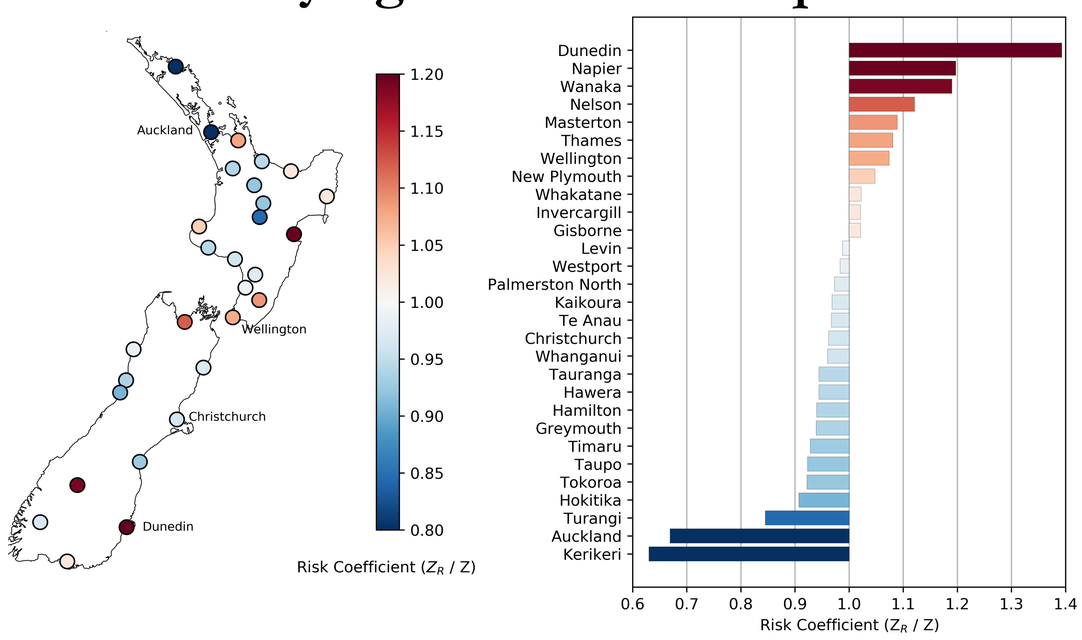



## 2. Existing Variability in Risk With NZS1170.5




National seismic hazard map used to define Z-Factor (Left) and estimated variability in collapse risk using standard fragility curve tied to hazard level on the left. Variability in the risk map is entirely due to different shapes of the hazard curve which are currently ignored in NZS1170.5

## 3. Modifying Z-Factor for Equal Risk

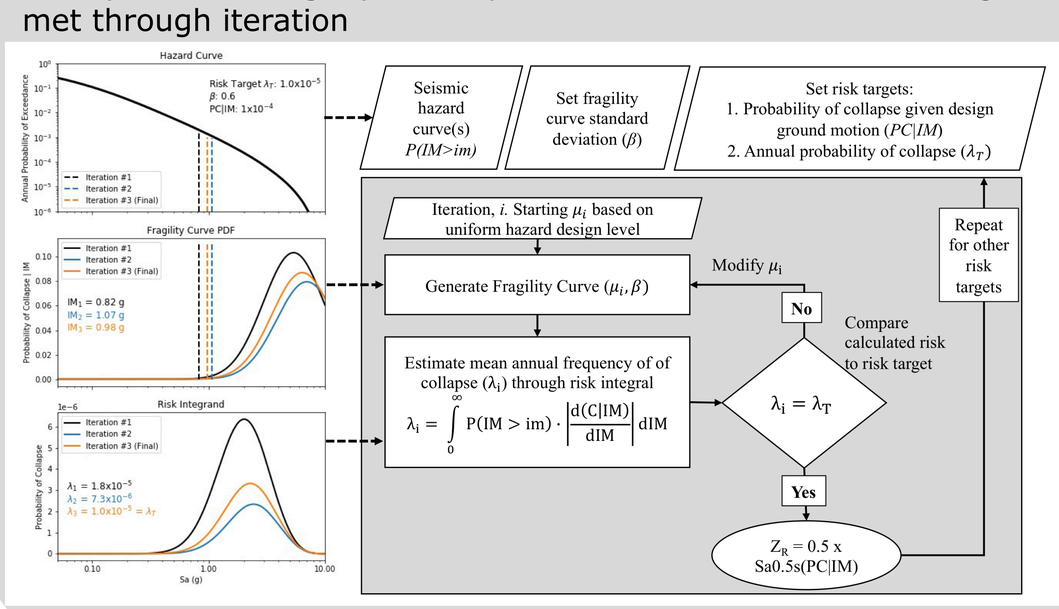



Using the Risk Targeted Hazard Spectra method we can estimate $Z_R$ the Risk Targeted Z-Factor which results in equal risk across New Zealand. The Risk Coefficient (Cr) shown above is the ratio of $Z_R$ to existing Z values in NZ1170.5.

## Risk Targeted Hazard Spectra

Steps for calculating risk targeted spectra:

1. Define risk target (i.e. $10^{-6}$ annual individual fatality risk)
2. Define fragility standard deviation
3. Define probability of collapse/limit state given design ground motion
4. Estimate risk target through the risk integral
5. Modify median fragility curve parameter until desired risk target is met through iteration

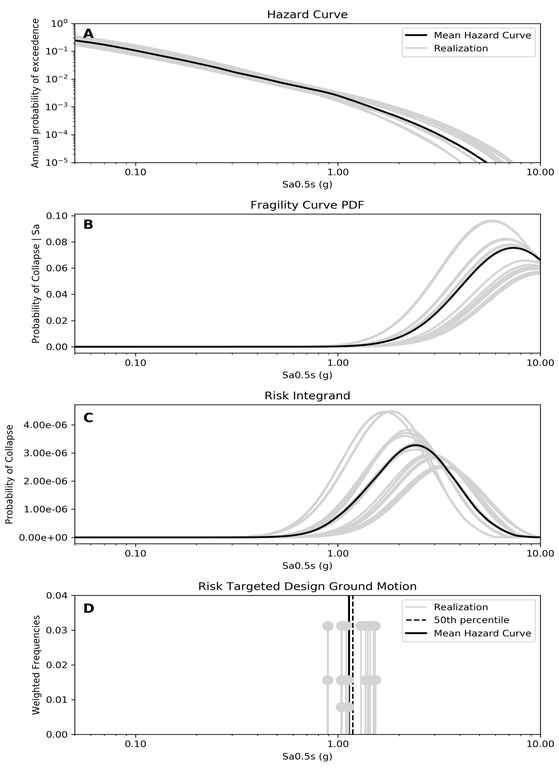



## 4. Epistemic Uncertainty in Seismic Hazard

Risk targeted hazard studies have typically ignored epistemic uncertainty in hazard, using only the mean hazard curve.

The update to the National Seismic Hazard Model will likely have complex logic trees therefore we show how epistemic uncertainty can be propagated through risk targeted hazard calculations for each logic tree branch. This results in a distribution of risk targeted hazard design ground motions.

Users can then select appropriate values from this distribution depending on their risk aversion.

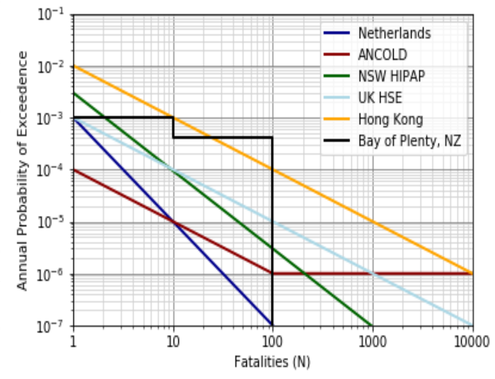



## 5. Including Additional Risk Targets

The examples here have been shown for life safety risk. Using the same framework additional risk measures such as economic loss, or functional recovery/downtime can be included. Appropriate fragility functions for these additional risk measures are required.

## 6. Addressing Societal Risk

Risk targeted hazard still only address individual building risk. However, it can be expanded to include societal risk; how risk aggregates to a city level defined as the annual probability of exceeding N fatalities. City risk limits can be defined and then this limit can be proportioned across each building to ensure the aggregated risk for a city is societally acceptable. The figure to right shows existing risk limits around the world.




## Key Points

- Uniform hazard results in non-uniform risk across New Zealand
- Using alternative approaches such as Risk Targeted Hazard Spectra can achieve objectives of uniform risk
- By moving to a risk targeted loading philosophy, alternative risk metrics such as downtime/functionality/economic loss can be included in performance objectives
- Risk also allows societal risk or risk aggregation to be included, where performance objectives for cities as well as individual buildings can be defined
- The framework is consistent and transparent and can be easily codified